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Physical and Chemical Factors Affecting the Efficiency of Washing Sweet Corn

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PHYSICAL AND CHEMICAL FACTORS AFFECTING THE EFFICIENCY OF WASHING SWEET CORN

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One of the most important factors in determining the quality of processed fruits and vegetables is the quality of the raw product. A high quality raw product is usually processed with more efficiency than a low quality raw product due to less trimming and handling required to eliminate waste and extraneous material. Insects constitute the most critical problem confronting the food processor since they damage the raw product. This damage not only means extra labor in trimming and sorting, but could also serve as a source of contamination in the finished product by both insects and microorganisms.

The sweet corn canning industry is confronted with both the European corn borer and the corn earworm. The approach to the control of these insects may be divided into two phases:

1. Field control—specific planting and spraying practices, as recommended by experiment station horticulturists and entomologists, should be followed.
2. In-plant—practices within the plant that aid in the removal of earworms, corn borers, and their residues.

The field control practices developed to date do not provide complete insect control, so that the sweet corn processor is still faced with the problem of removal of insects and insect debris from corn for processing. Therefore, a study was undertaken to:

1. Evaluate the effects of specific types of washers and washing techniques for the removal of insect pests and their residues from sweet corn.

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[2]This study was initiated in 1955 as a contract project between the U. S. Department of Agriculture and the Ohio Agricultural Experiment Station.

2. Determine the value of chemicals such as irritants, detergents, and wetting agents in the removal of insects and their residues from sweet corn.

Review of Literature

There has been little published information concerning the inplant control of the European corn borer and corn earworm and the factors involved in the washing of vegetables for processing.

Some of the chemical and physical factors in the washing of tomatoes prior to processing were investigated by Gould, Geisman and Sleesman (6) and Geisman and Gould (5). These investigators used detergents to aid in the removal of *Drosophila* eggs and larvae. They also found that increasing the temperature of the soak water increased the removal of insects.

The Entomology Research Division of the Agricultural Research Service investigated the effect of soak water temperature, soak time, irritants, and light on corn earworm and borer removal (7). These investigators stated that pyrethrins were the best irritant and that soak water temperature should be 100° F to produce the most activity of the borers. Most of these studies were carried out in 3-gallon containers.

Gould *et al.* (6) also recommended the use of high pressure sprays for rinsing tomatoes after soaking. They reported that this operation increased the removal of *Drosophila* eggs and larvae. It would seem that rinsing with high pressure sprays would aid in removing insects and residues such as chemicals and insect debris from sweet corn.

Considerable effort has been spent on the field control aspects of the European corn borer and the corn earworm (4, 8). Although the field control precautions are not within the scope of this study, it would seem that a knowledge of the life cycles and feeding habits of these insects would be important to the quality control technologists and the sweet corn processors. This information could be helpful in determing if and when heavy infestations might be expected. Although the corn earworm attacks many cultivated crops, only sweet corn will be considered here. The eggs are usually laid on corn silk. When hatched, the larvae feed downward following the silks into the ear tip. When full grown, the larvae enters the soil to pupate. The adult moth emerges and continues the cycle. In the North, there are usually two complete generations annually, while in the South there may be as many as five or more generations (2).

On the other hand, the European corn borer moth lays its eggs on the undersides of the corn leaves. When hatched, the larvae feed on immature leaves and tassels and eventually bore inside the stalk and into the ears. They pupate in the burrows and in ten to fourteen days the adult moths emerge to carry on the cycle. There are one or more generations a year depending on the length of the growing season (3).

MATERIALS AND METHODS

There were two phases of this work. One was in the pilot plant involving screening tests of irritants and detergents and evaluations of some of the physical and chemical factors affecting the washing of sweet corn. The other was concerned with commercial application of the techniques for washing sweet corn.

Raw Materials

For the pilot plant studies several varieties of sweet corn were used during the years 1957, 1958, and 1959 (Table 1). These varieties were selected to obtain a range of harvest dates. No difference was noted in the degree of insect infestation between varieties. It should be noted that the Tendermost variety had the characteristic of poor tip cover which led to excessive kernel damage by birds. This variety was unacceptable for this study and was not included in the later investigations.

The corn grew on the field plots of the Department of Horticulture and Forestry at Columbus, Ohio. An early and late planting of each variety were made each year in an effort to obtain as much borer infestation as possible. Acceptable cultural practices for Ohio were followed, although no pesticides were applied in order to obtain a high potential infestation of corn earworms and European corn borer.

The corn was harvested at different stages of maturity with three harvests being made in 1957, 15 made in 1958, and 13 in 1959.

TABLE 1.—Sweet Corn Varieties by Years Utilized in the Pilot Plant Studies.

Year	Variety	Seed Source
1957	Tendermost	Michael-Leonard
1958	Golden Beauty	Harris
	North Star	Harris
	Deep Gold	Woodruff
1959	North Star	Harris
	Golden Beauty	Harris
	Sugar King	Leatherman
	Victory Golden	Woodruff

Preparation and Processing

At each harvest the corn was brought to the Department of Horticulture Fruit and Vegetable Processing and Technology Pilot Plant, where it was husked on an FMC husker. The husked corn was then separated into lots as follows: (1) undamaged ears (2) ears with earworms (3) ears with borers and (4) ears with other damage. Lot 4 included ears with bird and sap beetle damage.

The undamaged ears were manufactured into cream-style corn which was utilized to determine the efficiency of insect detecting methods. The basic cream-style corn formula was as follows:

50 lbs. cream corn

3.5 lbs. sugar

0.35 lbs. salt

15 lbs. water

100 grams starch

Either whole worms or insect fragments in varying amounts were also added to each batch.

The ears with ear worms, borers, or other damage were either utilized in the screening tests or for pilot plant studies.

Screening Tests

In 1957, studies were conducted on a small scale to determine a range of effective soak times, soak temperatures, chemicals and chemical concentrations. These screening tests were carried out in a three-gallon container filled with two gallons of solution. Ten ears infested with either earworms or borers were added to the solution and the experiment was repeated three times. The temperature was changed from 70° to 130° F by 10-degree increments. The soaking period was varied from 1.5 to 6.0 minutes by 1.5 minute increments. Pyrethrins were used as an irritant and concentrations in these studies were 55.5, 62.5, 83.3, and 99.6 ppm. Malathion was also used as an irritant, but only at 83.3 ppm. In order to decrease surface tension and allow the irritant to spread uniformly throughout the solution, wetting agents and detergents were screened. The compounds and concentrations which were evaluated are shown in Table 2. The criteria used to determine whether the compounds were suitable were: degree of foaming, ease of use, compatibility with other chemicals, and color, odor and flavor of the corn after treatment.

Treatments which were not effective in removing earworms or borers were not evaluated further. Treatments, which were effective, were studied on a larger scale in the pilot plant.

TABLE 2.—Concentrations of Detergents and Wetting Agents Evaluated in the Screening Tests (1957).

Chemical	Concentration (parts per million)
Nonylphenol Ethylene Oxide	250, 500, 1000
Alkyl Ethylbenzyl Dimethyl Ammonium Chloride	500, 1000
Alkyl Dimethyl Benzyl Ammonium Chloride	500, 1000
Alkyl Aryl Sulfonate (powder)	100
Alkyl Aryl Sulfonate (liquid)	500
Klenzade fruit and vegetable washing compound	2500, 5000

Pilot Plant Studies

The pilot plant studies were carried out in the Department of Horticulture Fruit and Vegetable Processing and Technology Laboratory at The Ohio State University. Approximately 50 pounds of ears were placed in an 83-gallon soak tank which was equipped with air and steam lines (6). The time of soak was varied from 1.5 minutes to 6 minutes by 1.5 minute increments. The soak water was held at 100° F, and the ears were violently agitated during the soak period, then 2500 ppm of the fruit and vegetable washing compound were added to the soak water and either 83.3, or 99.6 ppm of pyrethrins were added. Each treatment was replicated at least three times.

Following the soak, the ears passed under a high pressure spray on a roller conveyor. Each ear made approximately three revolutions while under the spray. Four 18 SQ nozzles and two U 6520 nozzles (Spraying Systems Company nozzles) were mounted in a spray manifold.

Commercial Plant

In 1960 and 1961 the studies were carried out in a commercial plant. The sweet corn was obtained from local producers. Six harvest dates were selected each year. Samples of various lots were assayed to determine the degree of infestation of earworm and borers. The treatments, which resulted in the highest reduction in the insect contaminants in the pilot plant studies, were adapted for use in the commercial plant. During 10-minute intervals after the application of the treatment, all of the ears (approximately 1000 pounds) were examined. Six replications of each treatment were made in order to statistically analyze the treatments (9).

Determination of Insect Fragments

In the screening tests, pilot plant, and commercial plant tests, the number of insects remaining on the ears was determined by examining the ears immediately after treatment. However, in order to detect foreign matter in the finished products, a method for examining the contents of a can of cream-style corn must be available. Since the offical method (1) for insect fragment recovery involved specialized techniques and equipment, a simpler, more rapid method was developed.

The details of the procedure are as follows:

1. Shake can thoroughly (at least 200 times in an up-and-down motion parallel to the main axis of the body).
2. Open can and pour entire contents into a glass tray (8″ × 14″).
3. Place the tray over an incandescent (25 to 50 watt) light and survey the contents. Record the number of macroscopic fragments.
4. After thoroughly mixing entire contents on the tray, remove a 200-gram sample.
5. Transfer the sample to an 8-mesh screen placed in a bowl and wash the kernels with warm (100-130° F) water. Use sufficient water to cover the kernels (about 1200 cc).
6. Shake screen thoroughly to remove the cream portion of the corn and remove screen from the bowl.
7. Add 25 to 50 grams of Rhozyme H-39 to the solution of the corn and stir thoroughly until all of the enzyme is dissolved.
8. Heat the solution to 150° F and allow to digest at this temperature for 15 minutes.
9. Filter the solution through 10XX bolting cloth or sharkskin filter paper seated in a No. 5 Buchner funnel. Use 4-5 cloths or papers. Filtering can be aided by the use of vacuum applied to the filter flask.
10. With the aid of a 10- or 20X wide field microscope, examine the filters and record the number of insect fragments.

RESULTS AND DISCUSSION

Of the insects encountered, the corn earworm was found to be the easiest to remove from the sweet corn. Earworms were usually found on the tip of the ear where most of them could be removed in the husking operation. Further, when the ears were husked, the earworms which remained could be removed by the washing, rinsing, and conveying operations normally used in the processing of sweet corn. This was not true in the case of the European corn borer larvae and therefore, the primary emphasis of this study was to determine the effect of various physical and chemical factors on the removal of corn borer larvae.

The results of this study will be presented by discussing in sequence each of the variables involved in removing European corn borer larvae

TABLE 3.—Average Percent Reduction of European Corn Borer Larvae as Affected by Soak Water Temperature at a Constant (3-minute) Soak Period during the 1957 Season.

Soak Water Temperature (°F)	Average Number of Larvae per Replicate	Total Number of Larvae	Average Percent Reduction
70	13.3	40	27.50
100	13 0	39	82.05
110	11.3	34	64.70
130	15.3	46	73.91

from sweet corn. These include the physical factors of: soak temperature, soak time, agitation, and spray-rinse, and the chemical factors of irritants and detergents. They will be discussed in order of the unit operation and additives to each operation as encountered in the manufacture of canned sweet corn.

Soak Temperature

Screening tests were conducted on a small scale in order to exclude as many treatments as possible from the pilot plant studies. Since the literature indicated that soak temperature was a critical factor in insect removal, this aspect was investigated in screening tests. The temperature was varied from 70° F to 130° F and the results are shown in Table 3.

The data in Table 3 indicated that the greatest reduction in larvae was obtained at 100° F. This was in agreement with the results reported by Mason (7). However, it should be noted that as soak temperature increased above 100° F the removal of European corn borer larvae was decreased. Upon examination of the larvae which had been exposed to 130° F for three minutes, it was found that all of them were dead. Since the dead borers, being unable to move, would be more of a potential contaminant to the finished product than live ones, a study was undertaken to determine the maximum temperature which would not kill the larvae. This study revealed that an exposure at 115° F for three minutes was lethal. Thus, at this temperature or above, the borers which had not reached the surface of the ears would be killed and unless removed by trimming, would be a source of contamination in the finished product.

Soak Period

In the pilot plant, using a soak temperature of 100° F, the soak period was varied from 1.5 to 6.0 minutes by 1 5 minute increments. Each treatment was replicated five times during the 1958 season and five times during the 1959 season. The results are shown in Table 4.

TABLE 4.—Average Percent Reduction of European Corn Borer Larvae as Affected by Soak Period at 100° F during the 1958 and 1959 Seasons (Average of 10 replicates).

Soak Period (min.)	Average Number of Larvae	Average Percent Reduction
1.5	49	71.5
3.0	28	82.0
4.5	69	89.8
6.0	46	93.5

L.S.D. .05 = 3.11   L.S.D. .01 = 4.24

From Table 4, the data indicated that as soak time was increased the removal of European corn borer larvae was significantly increased. Considering this factor alone, the longer time would seem more desirable. However, when the increase in percent reduction per increment in time was considered, the data indicated that the differences between 1.5 and 3.0 minutes and 3.0 and 4.5 minutes were highly significant but the difference between 4.5 and 6.0 minutes were only significant at the .05 level. Therefore, the extended soak period up to 6.0 minutes was not considered desirable from the standpoint of increased removal of larvae. Both the 3.0 and 4.5-minute soak periods were more economically feasible than the 6.0-minute period and as will be shown later were more desirable.

Chemicals

Using a soak temperature of 100° F and soak times varying from 3.0 to 6.0 minutes, the value of adding chemicals to the soak water was determined. The use of irritants to stimulate the larvae and cause them to crawl to the surface of the ear was suggested by Mason (7). After the initial screening tests with irritants, it was found that the frass was unaffected. In order to aid in removal of debris, to serve as a "spreader" to carry the irritants throughout the soak tank, and to decrease the surface tension to allow for greater penetration of the irritants into the ears, several wetting agents and detergents were evaluated. The wetting agents were undesirable due to either having a high foaming characteristic or producing a strong odor and/or flavor in the corn. Only the fruit and vegetable washing compound produced the desired results. There was no noticeable difference in results between concentrations of either 2500 or 5000 ppm and therefore 2500 ppm of this detergent were utilized.

Pyrethrums, containing piperonyl butoxide as a synergist, and malathion were evaluated as irritants. For screening purposes, the

TABLE 5.—Average Percent Reduction of European Corn Borer Larvae as Affected by Various Pyrethrum Concentrations and Soak Periods (Soak Temperature 100° F with 2500 ppm Detergent Added to Two Gallons of Solution).

Pyrethrum Concentration (parts per million)	Soak Time (min.)	Average Number of Larvae	Average Percent Reduction
55.5	3.0	22	36.4
	4.5	19	36.8
	6.0	20	35.0
62.5	3.0	19	36.8
	4.5	22	36.4
	6.0	21	42.8
83.3	3.0	20	70.0
	4.5	21	66.7
	6.0	23	73.9
99.6	3.0	24	70.8
	4.5	25	68.0
	6.0*	26	60.9

*Dead larvae were found in this lot.

Soak Period—N.S. Pyrethrum Concentration L.S.D. .05 = 7.77
L.S.D. .01 = 10 45

concentrations of pyrethrums of 55.5, 62.5, 83.3, and 99.6 ppm were investigated in combination with soak periods varying from 3.0 to 6.0 minutes by 1.5 minute increments (Table 5).

The data in Table 5 indicated that there was no difference in removal of larvae between soak periods, however, there was a highly significant difference between pyrethrum concentrations. Pyrethrum concentrations of 83.3 and 99.6 produced significantly higher reductions than either the 55.5 or 62.5 ppm concentration. There was no significant difference between 83.3 and 99.6 ppm, except that at a soak period of 6.0 minutes using 99.6 ppm pyrethrum, several dead larvae were found which resulted in a lower percent reduction than either of the shorter soaking periods or 83.3 ppm soak period. Therefore, concentrations of 55.5 and 62.5 ppm pyrethrums were eliminated from further study in the pilot plant.

It was hoped that malathion would prove to be a satisfactory irritant since it was less expensive than either of the pyrethrum mixtures. An 83.3 ppm malathion solution was prepared and ears containing borer larvae were immersed for 3.0 and 4.5-minute soak periods. Five replications of these experiments produced an average of 68 0 percent reduction for 3.0-minute soak and an average of 80.0 percent

TABLE 6.—Average Percent Reduction of European Corn Borer Larvae as Affected by Various Pyrethrum Concentrations and Soak Periods (Soak Temperature 100°F with 2500 ppm Detergent Added to 83 Gallons of Solution).

Pyrethrum Concentration (parts per million)	Soak Time (min.)	Average Number of Larvae	Average Percent Reduction
83.3	3.0	46	82.6
	4.5	44	90.9
99.6	3.0	47	82.9
	4.5	48	93.7

Soak Time—N.S. Pyrethrum Concentration—N.S.

reduction for the 4.5-minute soak. These reductions were similar to those obtained with pyrethrums; however, the sweet corn subjected to these treatments developed a strong odor. For this reason malathion was eliminated from the pilot plant studies.

The treatments which appeared to give the best reduction in the screening test were evaluated five times and the average results are shown in Table 6.

From Table 6, it can be seen that as pyrethrum concentration increased, there was little increase in removal of borers. At both concentrations, the percent reduction increased as soak time increased. It should also be noted that the average percent reductions obtained in the pilot plant were much higher than those obtained in the screening tests (Tables 5 and 6). This was probably due to the air agitation in the soak tank.

Agitation

Vigorous air agitation of ears during the soaking period was perhaps one of the most important factors in the removal of European corn borer larvae from sweet corn. This was demonstrated by the increased percent reduction obtained in the pilot plant studies as compared to that obtained in the screening test (Table 7).

The data in Table 7 indicated that in the pilot plant the percent reduction was increased by 12.6 and 12 1 percent during the 3.0-minute soak period and by 24.2 and 25.7 percent during the 4.5-minute soak period. It should be noted that increase in pyrethrum concentration had little effect on increased larvae removal and that in the 4 5-minute soak period only a slight increase in removal was obtained as compared tc the results of the 3.0-minute soak.

The most plausible explanation of the increase in percent reduction obtained in the pilot plant over that obtained in the screening tests

TABLE 7.—Difference in Percent Reduction of European Corn Borer Larvae by Various Treatments Between Screening Tests and Pilot Plant (100° F Soak Temperature with 2500 ppm Detergent Added).

Pyrethrum Concentration (parts per million)	Soak Time (min.)	Percent Reduction Screening Tests	Percent Reduction Pilot Plant	Difference in Percent Reduction
83.3	3.0	70.0	82.6	12.6
	4.5	66.7	90.9	24.2
99.6	3 0	70.8	82.9	12.1
	4.5	68.0	93.7	25.7

Pyrethrum Concentration—N.S.
Soak Period —N.S. Difference—N.S.

seemed to be the method of agitating the ears during the soaking period. In the screening tests, the ears were stirred with a paddle which produced little exposure to air. In the pilot plant soak tank, vigorous agitation was produced by bubbling air through the water. Thus, the longer the soak period the longer the exposure to air agitation resulting in increased removal of larvae.

It was also noticed that borers became very irritated after soaking in a pyrethrum solution, if they were exposed to a direct draft of air. This would seem to further substantiate the explanation of increased larvae removal due to air agitation.

Limited studies were conducted to determine the effect of a supplemental airblast treatment on removal of borers. The data from these experiments are given in Table 8, with similar data given for treatments without an airblast for comparative purposes.

These data (Table 8) indicated an exposure to air after soaking increased the removal of corn borer larvae after a 3-minute soaking period but resulted in little increase in percent reduction after a 4.5

TABLE 8.—Average Percent Reduction of European Corn Borer Larvae Obtained at Various Soak Times With and Without an Air Blast Treatment (Soak Water at 100° F With 83.3 ppm Pyrethrums and 2500 ppm Detergent Added).

Soak Time (min.)	Without Air Blast		With Air Blast	
	Initial No. Borers	Average Percent Reduction	Initial No. Borers	Average Percent Reduction
3.0	46	82.6	27	96.3
4.5	44	90 9	27	92.6

Soak Times—N.S. Air Treatments—N.S.

minute soaking exposure. Since the treatments were identical except for the airblast, it would seem that air or air agitation was highly important in removal of insects and insect contamination from sweet corn.

Spray Rinsing

Following the soaking operation, a high pressure spray rinse was used. The primary purpose of this operation was to remove insects, insect debris, silk and chemicals from the surface of the ear. The ears passed under the sprays while on a roller conveyor. Each ear made at least three revolutions while under the spray manifold. Spray pressures were varied from 100 psi to 150 psi by 10 psi increments. The main criteria for selecting the proper spray pressure was removal of insect debris, silk, and chemicals. At all the pressures below 150 psi, insects and the chemicals used in soaking were removed but corn silk and insect debris were not. Only at 150 psi was the silk and insect residue removed.

Commercial Operation

After completing the pilot plant studies, the treatments which appeared to give the best reduction in European corn borer larvae were evaluated in a commercial corn canning plant. The treatments which were evaluated were as follows:

1. As a control lot, cold water soaking and normal rinsing were used.
2. A 3.0-minute soak at 100° F with vigorous agitation using 83.3 ppm pyrethrums and 2500 ppm detergent. This was followed with a 150 psi spray rinse.
3. A 4.5-minute soak with all other factors the same as in 2 above.
4. A 3.0-minute soak using 99.6 ppm pyrethrums with all other factors the same as in 2 above.
5. A 4.5-minute soak with all other factors the same as in 4 above.

The initial contamination was established by examining samples prior to husking. An average of 85 percent of all the ears contained European corn borer larvae at the time of the experiments. Each treatment was replicated six times in 1960 and six times in 1961. The exception to this was with lots 4 and 5. These lots were only replicated twice and then were eliminated from further study. There were two primary reasons for eliminating the 99.6 ppm pyrethrum concentrations. First, with increased agitation in the commercial plant a disagreeable odor was noticed and secondly, the increased concentration did not result in increased removal of insects.

After treatment, all of the ears in each lot were examined. Since approximately 1000 pounds of ears were collected, this would mean that approximately 2000 ears were examined for each replication of each treatment. With the initial contamination established at 85 percent, there were approximately 1700 borer larvae in each lot. The number of larvae remaining in the corn were recorded. The results indicated that in the control lot an average of 60 percent of the larvae were removed. These ears were returned to the line and the remaining insects were trimmed out. In both the 3.0 and 4.5-minute soak (lots 2 and 3 above), all the insect larvae were removed without trimming. Thus the results indicated that a 3.0-minute soak combined with 83.3 ppm pyrethrums and 2500 ppm detergent in 100° F water would be most desirable since the ears were free of borers after treatment. From this standpoint a 4.5-minute soak with the other factors the same would not be economical since increased reduction was not obtained. Furthermore, the 3.0-minute soak combined with the other factors resulted in less trimming which increased efficiency, production and quality of the finished product.

GENERAL DISCUSSION

Flavor Evaluation. Since it was necessary to use pyrethrums and detergent in the soak water, sweet corn was soaked in a solution of 83.3 ppm pyrethrums and 2500 ppm detergent at 100° F for 3 minutes. Triangular taste panels were used to evaluate this treatment for off-flavor. The panel could not distinguish between treated and untreated sweet corn in three replicated tests. Therefore, it was concluded that at 83.3 ppm pyrethrums, no off flavors or undesirable flavors were produced.

Amount of Insect Damage. In 1959, the amount of damaged ears and the percent of damaged kernels per ear were determined on the sweet corn grown for pilot plant use, that is, those with no pesticide treatment. The corn early in the season (late July) had 50 percent damaged ears; *i.e.,* ears with insect damage. In midseason (mid-August) the number of ears with insect destruction increased to approximately 67 percent. At the end of the season (early September), 95 to 100 percent of the ears had been infested with insects. The number of damaged kernels per ear did not follow this same pattern (Table 9).

The data indicated that the percent of damaged kernels in midseason was approximately double that of both the beginning and end of the season The total number of damaged kernels increased throughout the season since the percent of damaged ears increased. There also seemed to be a parallel between the percent of damaged kernels and

TABLE 9.—Average Percent Damaged Kernels Per Ear During the 1959 Season (3 replications).

Harvest	Number of Ears per Replicate	Average Percent Kernel Damage per Ear
Late July	100	5.67
Mid-August	100	11.63
Early September	100	6.62

European corn borer larvae population. When the amount of damaged kernels per ear was low, the borer population was high. Thus, a quality control technologist could use the percent of kernel damage per ear as a tool to indicate when it would be necessary to add pyrethrums and detergents to the soak water.

Metamorphic Stage of the Insect

The metamorphic stage of the insects should be considered. At several times during the season, several ears were found which contained both European corn borer and ear worm pupae. In all cases, regardless of the treatment given, the pupae were not removed. Pupae were usually covered with a silky web and attached to the cob by a mucilagenous substance. Therefore, if either of these insects were found in this stage of development, it would seem that trimming would be necessary to remove them Furthermore, it was noted that the smaller insect larvae (younger) reacted more violently to the irritant than did the older, larger larvae.

SUMMARY AND CONCLUSIONS

These studies on the washing of sweet corn to remove insect pests and their residues were divided into two aspects. These were (1) screening tests and pilot plant studies, and (2) commercial evaluation of the techniques.

The primary emphasis of this investigation was concerned with two unit operations; washing and rinsing. The principal conclusions drawn from this study are as follows:

1. Of the insects encountered, European corn borer larvae were the most difficult to remove from sweet corn.

2. At temperatures above 115° F in the soak water, European corn borer larvae were killed and many of the dead borers could only be removed by trimming.

3. A soak temperature of 100° F at constant soak period was most effective in removing European corn borer larvae from sweet corn.

4. In the pilot plant at a soak temperature of 100° F, both 3.0 and 4.5-minute soak periods produced highly significant reductions in European corn borer larvae.

5. With both soak time and temperature constant, 83.3 and 99.6 ppm pyrethrums in combination with 2500 ppm detergent produced significant reductions of European corn borer larvae.

6. Air agitation, during soaking increased the effectiveness of the irritants.

7. A high pressure spray rinse of 150 psi using two banks of full cone nozzles and one bank of knife type nozzles was most effective in removing insects, insect debris, and corn silk from sweet corn.

8. A combination of vigorous air agitation during a 3.0-minute soak in 100° F water containing 83.3 ppm pyrethrums and 2500 ppm detergent (Fruit and Vegetable Washing Compound) followed by a high pressure spray rinse of 150 psi, resulted in complete removal of European corn borer larvae and a reduction of the amount of trimming necessary for the manufacture of canned sweet corn in a commercial operation.

9. It would not be necessary to use elevated soak temperatures and chemicals for washing sweet corn throughout the season. This treatment would only be necessary when European corn borer larvae were present.

10. There were no off-flavors produced by 83.3 ppm pyrethrums.

11. The use of vigorous agitation during normal washing of sweet corn followed by a high pressure (150 psi) spray rinse should reduce the amount of hand labor and result in a more efficient operation.

RECOMMENDATIONS

1. When there is evidence of European corn borer larvae, sweet corn for processing should be soaked in water for three minutes at a temperature of 100° F while being vigorously agitated. The soak water should contain 83.3 ppm pyrethrums and 2500 ppm of detergent.

2. A thorough rinsing at 150 psi should follow the soaking operation. The water should be fresh so as not to recontaminate the sweet corn. The ears should make at least three revolutions while under the sprays. The nozzles should be placed seven inches above the roller conveyor. The spray manifold should include at least two banks of full cone nozzles which deliver a square spray pattern and one bank of knife type nozzles. The number of nozzles will be determined by

the width of the conveyor and the length necessary to accomplish at least three revolutions of the ears while under the sprays.

3. It is not necessary to use irritants and detergents at all times during the sweet corn season since there are periods during the harvest that insects are not a problem. The time that these treatments would most probably be necessary would be at the beginning and end of the season when European corn borer populations are high.

4. For calculations or making dilutions of pyrethrums and methods of determining pyrethrum concentration in the soak water, the manufacturers of these chemicals should be consulted.

5. Vigorous agitation of the ears during washing followed by a high pressure spray rinse as recommended above should be employed throughout the sweet corn processing season.

6. These recommendations for washing sweet corn are merely an aid in packing a quality product free of contamination due to insects. Good production and handling practices must precede the factory operations in order to insure satisfactory control of the insects infesting this crop.

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